UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution is unlimited
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) CR 87-01	5. MONITORING ORGANIZATION REPORT NUMBER(S) CR 87-01
6a. NAME OF PERFORMING ORGANIZATION Science Applications International Corp. 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION Naval Environmental Prediction Research Facility
6c. ADDRESS (City, State, and ZIP Code) 205 Montecito Avenue Monterey, CA 93940	7b. ADDRESS (City, State, and ZIP Code) Monterey, CA 93943-5006
8a. NAME OF FUNDING / SPONSORING ORGANIZATION Commander, Naval Oceanography Command 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N00228-84-D-3187
8c. ADDRESS (City, State, and ZIP Code) NSTL, MS 39529-5000	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. | PROJECT NO. | TASK NO. | WORK UNIT ACCESSION NO. DN656794

11. TITLE (Include Security Classification)

Severe Weather Guide - Mediterranean Ports - 1. Gaeta (U)

12. PERSONAL AUTHOR(S)

Englebretson, Ronald E. (LCDR, USN, Ret.) and Gilmore, Richard D. (CDR, USN, Ret.)

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 9/13/84 TO 11/1/86	1988, January	64

16. SUPPLEMENTARY NOTATION

Funding source: O & M, N-1

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	
04	02		Storm haven; Gaeta port; Mediterranean meteorology; Mediterranean oceanography

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This handbook for the port of Gaeta, one in a series of severe weather guides for Mediterranean ports, provides decision-making guidance for ship captains whose vessels are threatened by actual or forecast strong winds, high seas, restricted visibility or thunderstorms in the port vicinity. Causes and effects of such hazardous conditions are discussed. Precautionary or evasive actions are suggested for various vessel situations. The handbook is organized in four sections for ready reference: general guidance on handbook content and use; a quick-look captain's summary; a more detailed review of general information on environmental conditions; and an appendix that provides oceanographic information.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL Perryman, Dennis C., contract monitor	22b. TELEPHONE (Include Area Code) (408) 647-4709 | 22c. OFFICE SYMBOL 0&M,N-1

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

AN (1) AD-A191 316
FG (2) 040200
CI (3) (U)
CA (5) SCIENCE APPLICATIONS INTERNATIONAL CORP MONTEREY CA
TI (6) Severe Weather Guide - Mediterranean Ports. 1. Gaeta.
TC (8) (U)
DN (9) Final rept. 13 Sep 84-1 Nov 86,
AU (10) Englebretson, Ronald E.
AU (10) Gilmore, Richard D.
RD (11) Jan 1988
PG (12) 64
CT (15) N02284-84-D-3187
RN (18) NEPRF-CR-87-01
RC (20) Unclassified report
NO (21) See also 2, AD-A191 317.
DE (23) *PORTS, (FACILITIES), *WEATHER, HANDBOOKS, HAZARDS, LIMITATIONS, OCEANOGRAPHIC DATA, THUNDERSTORMS, VISIBILITY, WIND, ITALY, MEDITERRANEAN SEA, OCEAN WAVES, SHIPS, PROTECTION.
DC (24) (U)
ID (25) *Gaeta(Italy), WUDN656794.
IC (26) (U)
AB (27) This handbook for the port of Gaeta, one in a series of severe weather guides for Mediterranean ports, provides decision-making guidance for ship captains whose vessels are threatened by actual or forecast strong winds, high seas, restricted visibility or thunderstorms in the port vicinity. Causes and effects of such hazardous conditions are discussed. Precautionary or evasive actions are suggested for various vessel situations. The handbook is organized in four sections for ready reference: general guidance on handbook content and use; a quick-look captain's summary; a more detailed review of general information on environmental conditions; and an appendix that provides oceanographic information

Naval Environmental Prediction Research Facility
Monterey, CA 93943-5006
Contractor Report CR 87-01 January 1988

SEVERE WEATHER GUIDE: MEDITERRANEAN PORTS.

1. GAETA

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CONTENTS

FOREWORD

This handbook on Mediterranean Ports was developed as part of an ongoing effort at the Naval Environmental Prediction Research Facility to create products for direct application to Fleet operations. The research was conducted in response to Commander Naval Oceanography Command (CNOC) requirements validated by the Chief of Naval Operations (CNO).

As mentioned in the preface, the Mediterranean region is unique in that several areas exist where local winds can cause dangerous operating conditions. This handbook will provide the ship's captain with assistance in making decisions regarding the disposition of his ship when heavy winds and seas are encountered or forecast at various port locations.

Readers are urged to submit comments, suggestions for changes, deletions and/or additions to NOCC, Rota with a copy to the oceanographer, COMSIXTHFLT. They will then be passed on to the Naval Environmental Prediction Research Facility for review and incorporation as appropriate. This document will be a dynamic one, changing and improving as more and better information is obtained.

M. G. SALINAS
Commander, U.S. Navy

PORT INDEX

The following is a tentative prioritized list of Mediterranean Ports to be evaluated during the five-year period 1988-92, with ports grouped by expected year of the port study's publication. This list is subject to change as dictated by circumstances and periodic review.

1988 NO.	PORT
1	GAETA, ITALY
2	NAPLES, ITALY
3	CATANIA, ITALY
4	AUGUSTA BAY, ITALY
5	CAGLIARI, ITALY
6	LA MADDALENA, ITALY
7	MARSEILLE, FRANCE
8	TOULON, FRANCE
9	VILLEFRANCHE, FRANCE
10	MALAGA, SPAIN
11	NICE, FRANCE
12	CANNES, FRANCE
13	MONACO
14	ASHDOD, ISRAEL
15	HAIFA, ISRAEL
	BARCELONA, SPAIN
	PALMA, SPAIN
	IBIZA, SPAIN
	POLLENSA BAY, SPAIN
	VALENCIA, SPAIN
	CARTAGENA, SPAIN
	GENOA, ITALY
	LIVORNO, ITALY
	SAN REMO, ITALY
	LA SPEZIA, ITALY
	VENICE, ITALY
	TRIESTE, ITALY

1989	PORT
	SPLIT, YUGOSLAVIA
	DUBROVNIK, YUGOSLAVIA
	TARANTO, ITALY
	PALERMO, ITALY
	MESSINA, ITALY
	TAORMINA, ITALY
	PORTO TORRES, ITALY

1990	PORT
	BENIDORM, SPAIN
	ROTA, SPAIN
	TANGIER, MOROCCO
	PORT SAID, EGYPT
	ALEXANDRIA, EGYPT
	ALGIERS, ALGERIA
	TUNIS, TUNISIA
	GULF HAMMAMET, TUNISIA
	GULF OF GABES, TUNISIA
	SOUDA BAY, CRETE

1991	PORT
	PIRAEUS, GREECE
	KALAMATA, GREECE
	THESSALONIKI, GREECE
	CORFU, GREECE
	KITHIRA, GREECE
	VALETTA, MALTA
	LARNACA, CYPRUS

1992	PORT
	ANTALYA, TURKEY
	ISKENDERUN, TURKEY
	IZMIR, TURKEY
	ISTANBUL, TURKEY
	GOLCUK, TURKEY
	GULF OF SOLLUM

PREFACE

Environmental phenomena such as strong winds, high waves, restrictions to visibility and thunderstorms can be hazardous to critical Fleet operations. The cause and effect of several of these phenomena are unique to the Mediterranean region and some prior knowledge of their characteristics would be helpful to ship's captains. The intent of this publication is to provide guidance to the captains for assistance in decision making.

The Mediterranean Sea region is an area where complicated topographical features influence weather patterns. Katabatic winds will flow through restricted mountain gaps or valleys and, as a result of the venturi effect, strengthen to storm intensity in a short period of time. As these winds exit and flow over port regions and coastal areas, anchored ships with large 'sail areas' may be blown aground. Also, hazardous sea state conditions are created, posing a danger for small boats ferrying personnel to and from port. At the same time, adjacent areas may be relatively calm. A glance at current weather charts may not always reveal the causes for these local effects which vary drastically from point to point.

Because of the irregular coast line and numerous islands in the Mediterranean, swell can be refracted around such barriers and come from directions which vary greatly with the wind. Anchored ships may experience winds and seas from one direction and swell from a different direction. These conditions can be extremely hazardous for tendered vessels. Moderate to heavy swell may also propagate outward in advance of a storm resulting in uncomfortable and sometimes dangerous conditions, especially during tending, refueling and boating operations.

This handbook addresses the various weather conditions, their local cause and effect and suggests some evasive action to be taken if necessary. Most of the major ports in the Mediterranean will be covered in the handbook. A priority list, established by the Sixth Fleet, exists for the port studies conducted and this list will be followed as closely as possible in terms of scheduling publications.

RECORD OF CHANGES

CHANGE NUMBER	DATE OF CHANGE	DATE ENTERED	PAGE NUMBER	ENTERED BY

1. GENERAL GUIDANCE

1.1 DESIGN

This handbook is designed to provide ship captains with a ready reference on hazardous weather and wave conditions in selected Mediterranean harbors. Section 2, the captain's summary, is an abbreviated version of section 3, the general information section intended for staff planners and meteorologists. Once section 3 has been read, it is not necessary to read section 2.

1.1.1 Objectives

The basic objective is to provide ship captains with a concise reference of hazards to ship activities that are caused by environmental conditions in various Mediterranean harbors, and to offer suggestions for precautionary and/or evasive actions. A secondary objective is to provide adequate background information on such hazards so that operational forecasters, or other interested parties, can quickly gain the local knowledge that is necessary to ensure high quality forecasts.

1.1.2 Approach

Information on harbor conditions and hazards was accumulated in the following manner:

A. A literature search for reference material was performed.

B. Cruise reports were reviewed.

C. Navy personnel with current or previous area experience were interviewed.

D. A preliminary report was developed which included questions on various local conditions in specific harbors.

E. Port/harbor visits were made by NEPRF personnel; considerable information was obtained through interviews with local pilots, tug masters, etc; and local reference material was obtained (See section 3 references).

F. The cumulative information was reviewed, combined, and condensed for harbor studies.

1.1.3 Organization

The Handbook contains two sections for each harbor. The first section summarizes harbor conditions and is intended for use as a quick reference by ship captains, navigators, inport/at sea OOD's, and other interested personnel. This section contains:

A. a brief narrative summary of environmental hazards,

B. a table display of vessel location/situation, potential environmental hazard, effect-precautionary/evasion actions, and advance indicators of potential environmental hazards,

C. local wind wave conditions, and

D. tables depicting the wave conditions resulting from propagation of deep water swell into the harbor.

The swell propagation information includes percent occurrence, average duration, and the period of maximum wave energy within height ranges of greater than 3.3 feet and greater than 6.6 feet. The details on the generation of sea and swell information are provided in Appendix A.

The second section contains additional details and background information on seasonal hazardous conditions. This section is directed to personnel who have a need for additional insights on environmental hazards and related weather events.

1.2. CONTENTS OF SPECIFIC HARBOR STUDIES

This handbook specifically addresses potential wind and wave related hazards to ships operating in various Mediterranean ports utilized by the U.S. Navy. It does not contain general purpose climatology and/or comprehensive forecast rules for weather conditions of a more benign nature.

The contents are intended for use in both pre-visit planning and in situ problem solving by either mariners or environmentalists. Potential hazards related to both weather and waves are addressed. The oceanographic information includes some rather unique information relating to deep water swell propagating into harbor shallow water areas.

Emphasis is placed on the hazards related to wind, wind waves, and the propagation of deep water swell into the harbor areas. Various vessel locations/situations are considered, including moored, nesting, anchored, arriving/departing, and small boat operations. The potential problems and suggested pre-cautionary/evasive actions for various combinations of environmental threats and vessel location/situation are provided. Local indicators of environmental hazards and possible evasion techniques are summarized for various scenarios.

CAUTIONARY NOTE: In September 1985 Hurricane Gloria raked the Norfolk, VA area while several US Navy ships were anchored on the muddy bottom of Chesapeake Bay. One important fact was revealed during this incident: Most all ships frigate size and larger dragged anchor, some more than others, in winds of over 50 knots. As winds and waves increased, ships 'fell into' the wave troughs, BROADSIDE TO THE WIND and become difficult or impossible to control.

This was a rare instance in which several ships of recent design were exposed to the same storm and much effort was put into the documentation of lessons learned. Chief among these was the suggestion to evade at sea rather than remain anchored at port whenever winds of such intensity were forecast.

2. CAPTAIN'S SUMMARY

Gaeta Harbor is well protected from high wind and waves of the open ocean. It is considered a storm haven for vessels on the west coast of Italy with the knowledge that "if Gaeta is bad, no others are better" (Figure 2-1).

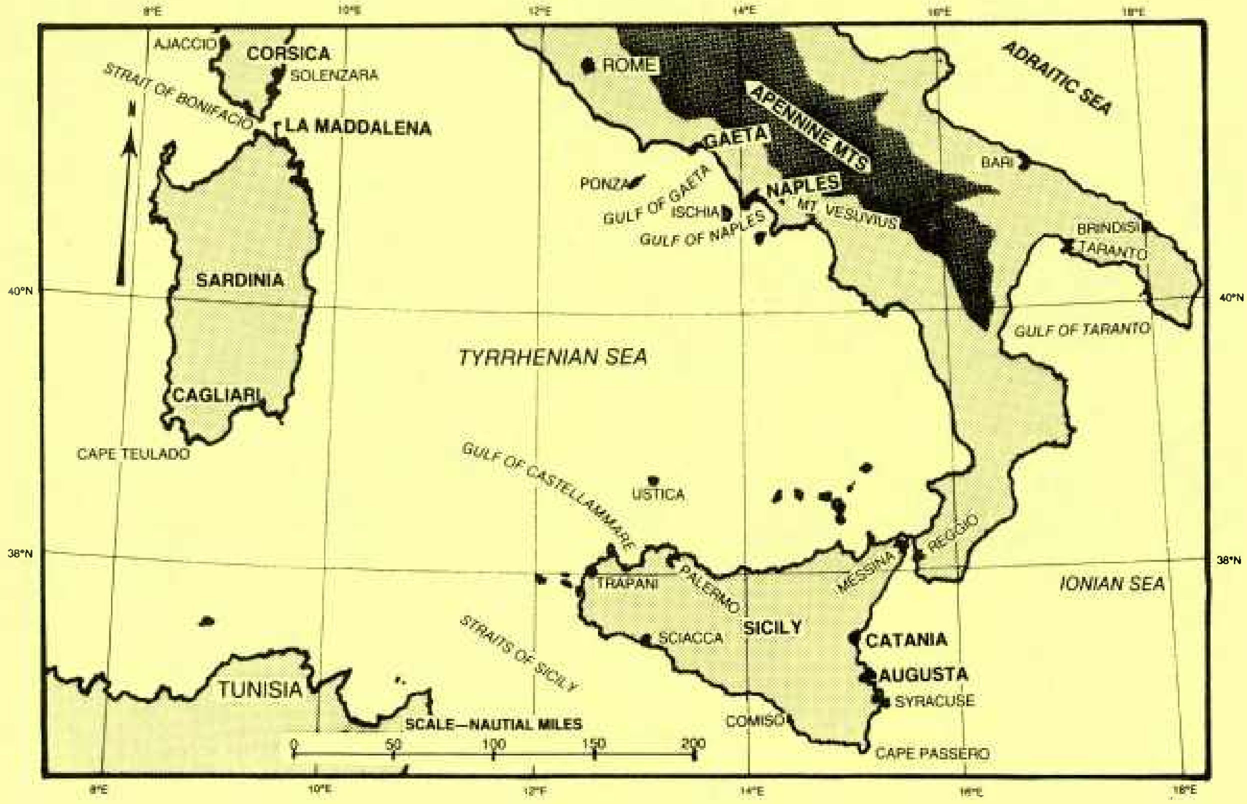


Figure 2-1. Ports of Italy, Sicily, and Sardinia.

Except for that portion north of Punta dello Stenardo, the Gulf of Gaeta is exposed to winds and waves from the southeast clockwise through west (Figure 2-2). The portion of the Gulf north of Punta dello Stenardo is exposed from the northeast through southeast.

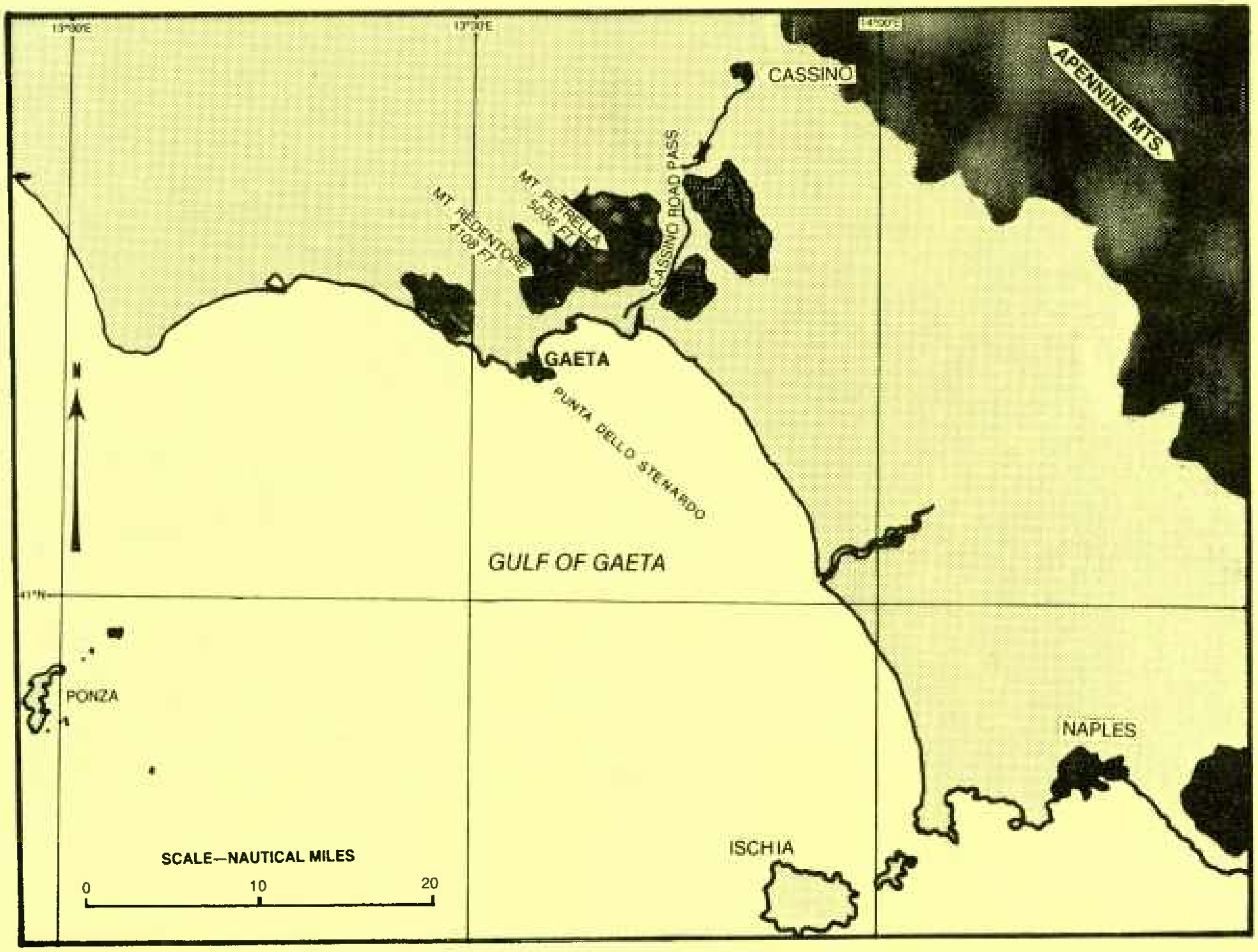


Figure 2-2. Gulf of Gaeta.

The harbor at Gaeta is well protected and is used as a storm haven by vessels on the west coast of Italy with the knowledge that 'if Gaeta is bad, no others are better'. The Gulf of Gaeta south of Punta dello Stenardo is exposed to winds and waves from the southeast clockwise through west. The portion of the Gulf north of Punta dello Stenardo is exposed to winds and waves from northeast through southeast. The inner harbor at Gaeta is protected on the east by a breakwater, thus limiting its exposure to wind waves generated in the limited fetch area north of the harbor entrance. The designated anchorage (point 1 of Figure 2-3) is located east of the breakwater that protects the inner harbor, but the promontory of Punta dello Stenardo provides protection for anchored vessels from most swell generated in the open sea. Most hazardous conditions result from local effects (i.e., funneling of winds around mountains, and land/sea breezes), and thus are not representative of the large scale open ocean conditions. Tides at the Port of Gaeta are generally negligible with a range of below 1 ft (0.3 m) (Lloyd's 1983). Currents are weak and relatively insignificant throughout the harbor. The harbor has a soft mud bottom and anchor dragging can be a problem in force 6 (22-27 kt) winds or greater.

Specific hazardous atmospheric conditions, vessel situations, and suggested precautionary/evasion action scenarios are summarized in Table 2-1. Hazards for both inport and at anchorage are addressed.

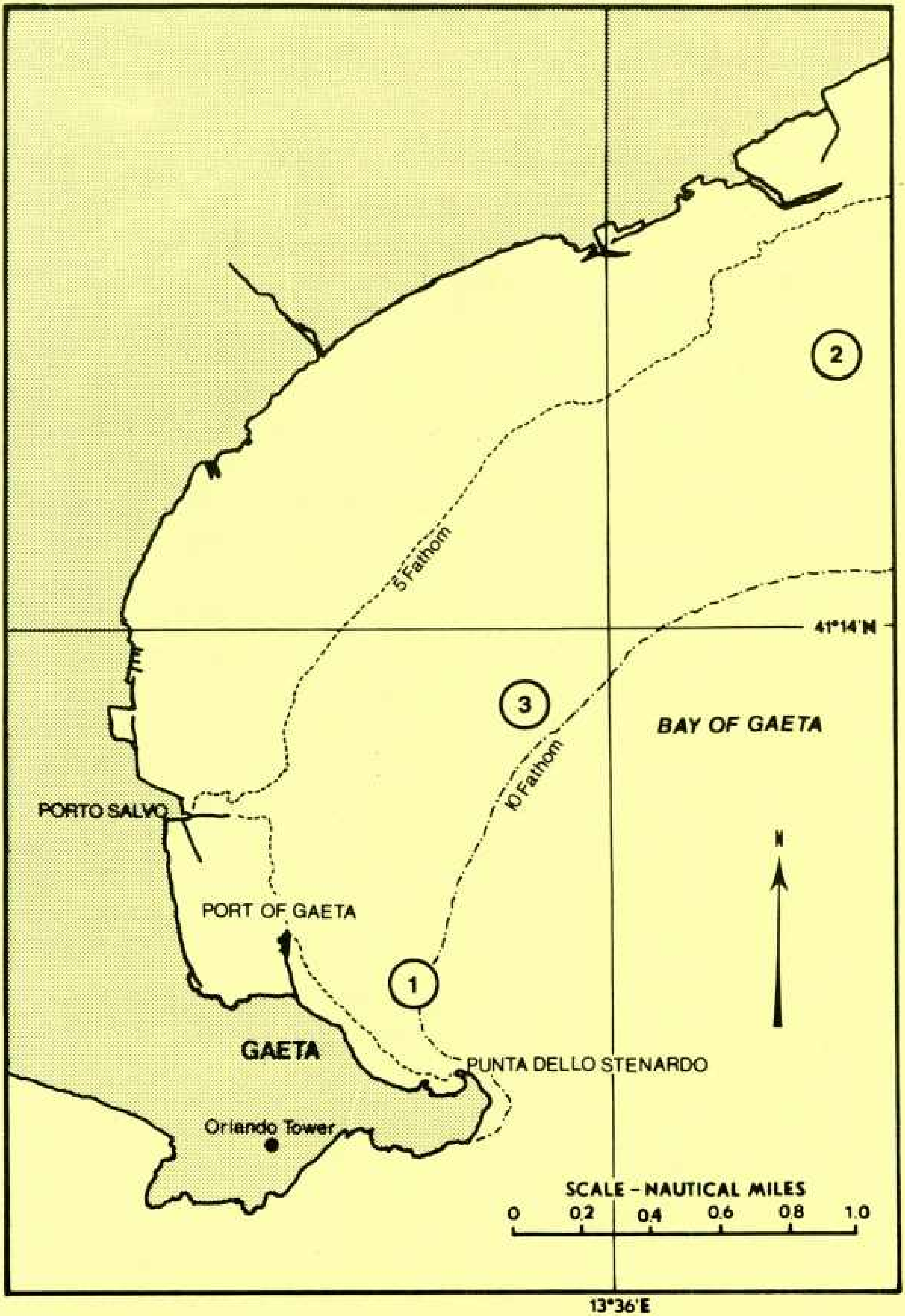


Figure 2-3. Port of Gaeta, Italy.

Table 2-1. Summary of hazardous environmental conditions for the Port of Gaeta, Italy.

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
1. Wind a. Tramontana - Strong ENE'ly winds known locally as Garigliano. * Strongest during late evening to mid-morning, weakest early afternoon. May reach force 8 (34-40 kt) or stronger, decreasing to force 5 (17-21 kt) in the early afternoon. * Occurs in winter and early spring.	Advance warning. * Fresh snow and/or small clouds on summits of mountains to north of Gaeta. * Winds may onset before snow is visible. Wind duration. * Persistent snow on mountains is indicator of continued high winds. * Velocities will decrease when low pressure center moves east of 15°E. Rota forecast. Calls for strong northerly winds over Italy. Winds are forecast over water areas only. Over land areas, winds can be estimated from isobar spacing.	(1) Moored - no nested vessels.	PORT PROTECTION MINIMIZES HIGH WIND THREAT: GAETA IS BEST HAVEN ON ITALY'S WEST COAST. (a) Wind may tend to force vessels off moorings. * Tug assistance may be required (b) Mooring or getting underway. * Vessel movement in harbor is restricted with force 6 (22-27 kt) or higher. (c) Small craft * Extra securing precautions required.
		(2) Moored with tended vessels nested.	(a) All winds * Movement in/out of nests restricted to less than force 5 (17-21 kt). (b) If winds back to N'ly * Nested vessels may shift.
		(3) Anchored in designated anchorage.	(a) Vessels may have to leave designated anchorage * Port Captain will order movement when winds reach force 6 (22-27 kt). * Highest winds can be avoided in NNW section of Bay of Gaeta (in lee of Apennine Mountains). * Bottom of designated anchorage is soft mud with good holding properties.
		(4) Arriving/departing harbor.	(a) Evolution should be completed before wind onset. * Vessel movement in harbor is restricted when winds reach force 6 (22-27 kt).
		(5) Small boat operations.	(a) Boating may be restricted. * Small boat operations will be cancelled to/from anchorages when wind/seas reach 40 kt/4-6 ft.
b. Mistral - Occurs at Gaeta as W'ly 30-35 kt. * Usually lasts for about 24 hrs. * Most severe in late autumn, winter, and spring. Uncommon in late summer. * Post-frontal winds are sometimes erroneously called Mistral, but the effect is similar.	Advance warning. * Wind warnings for Gulf of Lion (first indication of forthcoming winds), Strait of Bonifacio, and/or Tyrrhenian Sea. * If winds are actually post-frontal type rather than Mistral, they will follow a strong cold or occluded frontal passage	(1) Moored - no nested vessels.	(a) Remain at berth * W'ly wind will tend to keep vessel on mooring.
		(2) Moored with tended vessels nested.	(a) Remain nested * W'ly wind will tend to keep nest intact. * Nested vessels will not be moved in/out when winds reach force 5 (17-21 kt).
		(3) Anchored in designated Anchorage.	(a) Dragging anchor * If occurring, drift should be toward deeper water east of anchorage.
		(4) Arriving/departing harbor.	(a) Evolution should be completed before wind onset. * Vessel movement in harbor is restricted when winds reach force 6 (22-27 kt).
		(5) Small boat operations	(a) Boating may be restricted. * Small boat operations will be cancelled to/from anchorages when wind/seas reach 40 kt/4-6 ft.
c. Sea breeze. WNW'ly force 3 (7-11 kt) sea breeze routinely occurs during afternoons in summer. * Late spring to autumn phenomenon. * An enhanced sea breeze can exceed force 5 (17-21 kt).	Advance indicators of an enhanced sea breeze. * Rising atmospheric pressures west of Gaeta. * Diurnal pressure changes at Gaeta indicating an increase in atmospheric pressure to above the seasonal norm.	(1) Moored with tended vessels nested	(a) Moving vessels in/out of nest. * Evolutions should be scheduled for mornings to avoid increased afternoon winds. * Pilots will not bring a vessel in/out of a nest in winds of force 5 (17-21 kt) or greater.
2. SE to SW swell. * Most likely during late autumn, winter, or early spring. * Tend to last 1-2 days.	S'ly winds preceding passing frontal system and/or low pressure system. * Wind and swell directions will tend to remain in phase (i.e. from the same direction) except for a short period following a major wind shift.	(1) Moored - no nested vessels.	(a) Effect of swell. * Negligible - swell energy tends to be refracted to eastern part of Bay of Gaeta, raising a strong surf between Gaeta and Porto Salvo.
		(2) Anchored in designated anchorage.	(a) Small craft. * Small boating may be restricted.

Table 2-2 provides the height classification and direction of shallow water waves to expect at points 1, 2, and 3 (Figure 2-3) when the deep water wave conditions are known.

> Example: Use of Table 2-2 for Gaeta Point 3.
>
> Deep water wave forecast as provided by a forecast center or a reported/observed deep water wave condition:
>
> 8 feet, 10 seconds, from 210°.
>
> The expected wave condition at Gaeta Point 3, as determined from Table 2-2:
>
> 5-7 feet, 10 seconds, from 165°.

The Gaeta Point 3 conditions are found by entering Table 2-2 with the forecast or known deep water wave direction and period. The height is determined by multiplying the deep water height (8 ft) by the ratio of shallow to deep height (.6 to <.9).

NOTE: Wave periods are a conservative property and remain constant when waves move from deep to shallow water, but speed, height, and steepness change.

Table 2-2. Shallow water wave directions and relative height conditions versus deep water period and direction (see Figure 2-3 for location of points).

FORMAT: Shallow Water Direction
Height Conditions:

GAETA POINT 1:

Deep Water Period (sec)	6	8	10	12	14
Direction	115°	110°	110°	110°	100°
180°	.5	.4	.4	.4	.6
210°	110°	120°	115°	110°	110°
	.3	.3	.3	.4	.6

GAETA POINT 2:

Deep Water Period (sec)	6	8	10	12	14
Direction	180°	180°	180°	180°	180°
180°	.8	.8	.9	.9	.9
210°	210°	210°	210°	210°	200°
	.8	.8	.9	.9	.9
240°	240°	240°	235°	235°	235°
	.8	.8	.9	.9	.9

GAETA POINT 3:

Deep Water Period (sec)	6	8	10	12	14
Direction	175°	165°	160°	165°	160°
180°	.5	.5	.7	.8	.7
210°	165°	160°	165°	170°	160°
	.3	.3	.3	.3	.3
240°	175°	180°	180°	180°	180°
	.2	.2	.2	.2	.2

The local wind generated wave conditions for the anchorage area identified as point 3 near the center of the harbor (Figure 2-3) are given in Table 2-3. All heights refer to the significant wave height (average of the highest 1/3 waves). Enter the local wind speed and direction in this table to obtain the minimum duration in hours required to develop the indicated fetch limited sea height and period. The time to reach fetch limited height is based on an initial flat ocean. When starting from a pre-existing lower wave height, the time to fetch limiting height will be shorter.

Table 2-3. Gaeta Bay near point 3. Local wind waves for fetch limited conditions related to point 3 (based on JONSWAP model).

Format: height (feet)/period (seconds)
time (hours) to reach fetch limited height

Direction and\ Fetch \ Length \ (n mi)	Local Wind Speed (kt) 18	24	30	36	42
ENE 8 n mi	2/3 1-2	2-3/3-4 1-2	3/4 1-2	4/4 1-2	4-5/4-5 1-2
ESE 13 n mi	2-3/4 2	3-4/4 2-3	4/4-5 2	5/5 2	6/5 2
SSE 30 n mi	3-4/5 3	5/5-6 4	6/6 3-4	7/6 3-4	8/6-7 3

Example: To the south-southeast (150°) there is about a 30 n mi fetch (Figure 2-2). Given a south-southeast wind at 24 kt, the sea will have reached 5 feet with a period of 5 to 6 seconds within 4 hours. Wind waves will not grow beyond this condition unless the wind speed increases or the direction changes to one over a longer fetch length. If the wind waves are superimposed on deep water swell, the combined height may change in response to changing swell conditions. Wind wave directions are assumed to be the same as the wind direction.

Combined Wave heights are obtained by finding the square root of the sum of the squares of the swell and wind wave heights.

Example: Swell 10 ft, wind wave 5 ft.

$$\sqrt{10^2 + 5^2} = \sqrt{100 + 25} = \sqrt{125} \approx 11.2 \text{ ft}$$

Note: Increase over larger height is small. If both heights were equal, combined height would increase by a factor of 1.4. If one is half of the other, as in the example, increase over the larger of two is by a factor of 1.12.

Climatological factors of shallow water waves, as described by percent occurrence, average duration, and period of maximum energy (period at which the most energy is focused for a given height), are given in Table 2-4. See Appendix A for discussion of wave spectrum and energy distribution. The data is provided by season for two ranges of heights: greater than 3.3 feet and greater than 6.6 feet.

Three anchorage areas have been selected for Gaeta (Figure 2-3). Point 1 is just outside the inner harbor off shore from Punta dello Stenardo. Point 2 is in the northern portion of the Bay where vessels may move to escape the full effects of the local Tramontana. Point 3 is near the middle of the Bay in the general anchorage area.

Table 2-4. Shallow water climatology as determined from deep water wave propagation. Percent occurrence, average duration or persistence, and wave period of maximum energy for wave height ranges of greater than 3.3 feet and greater than 6.6 feet by climatological season.

GAETA POINT 1:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	11	6	2	10
Average Duration (hrs)	12	11	21	11
Period Max Energy(sec)	6	6	6	6
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	2	0	0	2
Average Duration (hrs)	8	NA	NA	9
Period Max Energy(sec)	9	NA	NA	9
GAETA POINT 2:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	15	9	4	13
Average Duration (hrs)	12	13	9	11
Period Max Energy(sec)	10	8	8	10
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	4	1	1	4
Average Duration (hrs)	8	9	8	9
Period Max Energy(sec)	14	12	12	12
GAETA POINT 3:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	13	8	4	14
Average Duration (hrs)	12	15	31	13
Period Max Energy(sec)	6	6	6	6
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	3	0	<<1	2
Average Duration (hrs)	8	NA	6	9
Period Max Energy(sec)	11	NA	11	11

SEASONAL SUMMARY OF HAZARDOUS WEATHER CONDITIONS

WINTER (November thru February):

* Tramontana (known locally as Garigliano) is cold, east wind which can reach 45 kt in harbor. Strongest at night.
* Mistral is west wind at Gaeta, 30-35 kt and normally lasts less than a day.

SPRING (March thru May):

* Early spring similar to winter.
* Tramontana still a threat thru April.
* Mistral still occurs but is weaker than in winter.
* Sea breeze infrequently reaches 20 kt.

SUMMER (June thru September):

* Tramontana can still occur in summer.
* Sea breeze daily occurrence and occasionally will disrupt afternoon operations.

AUTUMN (October):

* Short transition season with winter-like weather returning by end of month.

NOTE: For more detailed information on hazardous weather conditions see previous Summary Table in this section and Hazardous Weather Summary in Section 3.

REFERENCES

Lloyd's, 1983: Ports of the World. Lloyd's of London Press Ltd, Sheepen Place, Colchester, Essex, U. K.

3. GENERAL INFORMATION

This section expands on the material in the Captain's Summary. Paragraph 3.5 provides a general discussion of hazards and Table 3-5 provides a summary of hazards and actions by season.

3.1 Geographic Location

The Port of Gaeta is located at 41°13'00"N 13°35'29"E, about 70 n mi (130 km) southeast of Rome on Italy's west coast (Figure 3-1). Gaeta is positioned on the west side of Rada di Gaeta (Bay of Gaeta) at the north end of Golfo di Gaeta (Gulf of Gaeta).

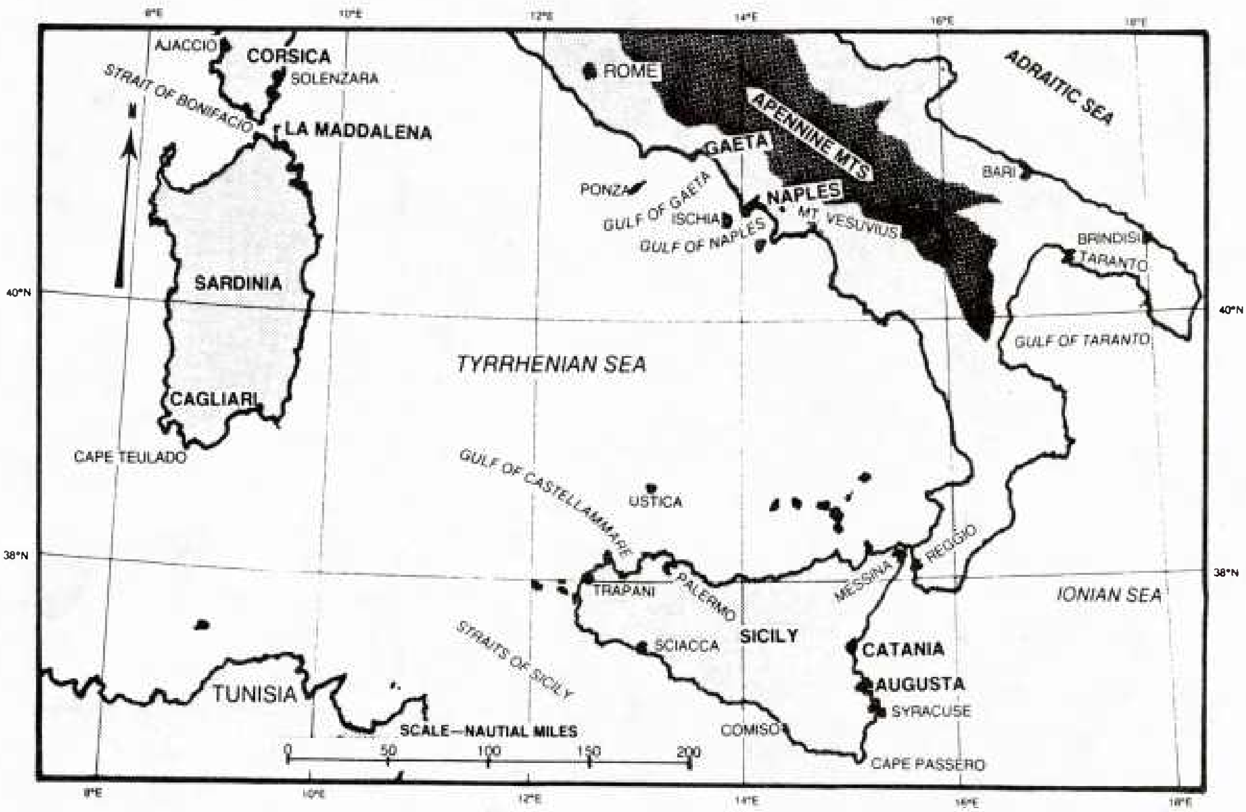


Figure 3-1. Ports of Italy, Sicily, and Sardinia.

The Gulf of Gaeta, with rather ill-defined boundaries, is situated some 30 n mi (56 km) northwest of Naples (Figure 3-2). Prominent landmarks include Mt. Petrella, a 5,036 ft (1,535 m) mountain about 8 n mi northeast of Punta dello Stenardo (a promontory on the northwest side of the Gulf of Gaeta), Mt. Redentore, a 4,108 ft (1,252 m) mountain near Mt. Petrella, and the 551 ft (168 m) Orlando Tower located some 3,445 ft (1,050 m) west-southwest of Punta dello Stenardo.

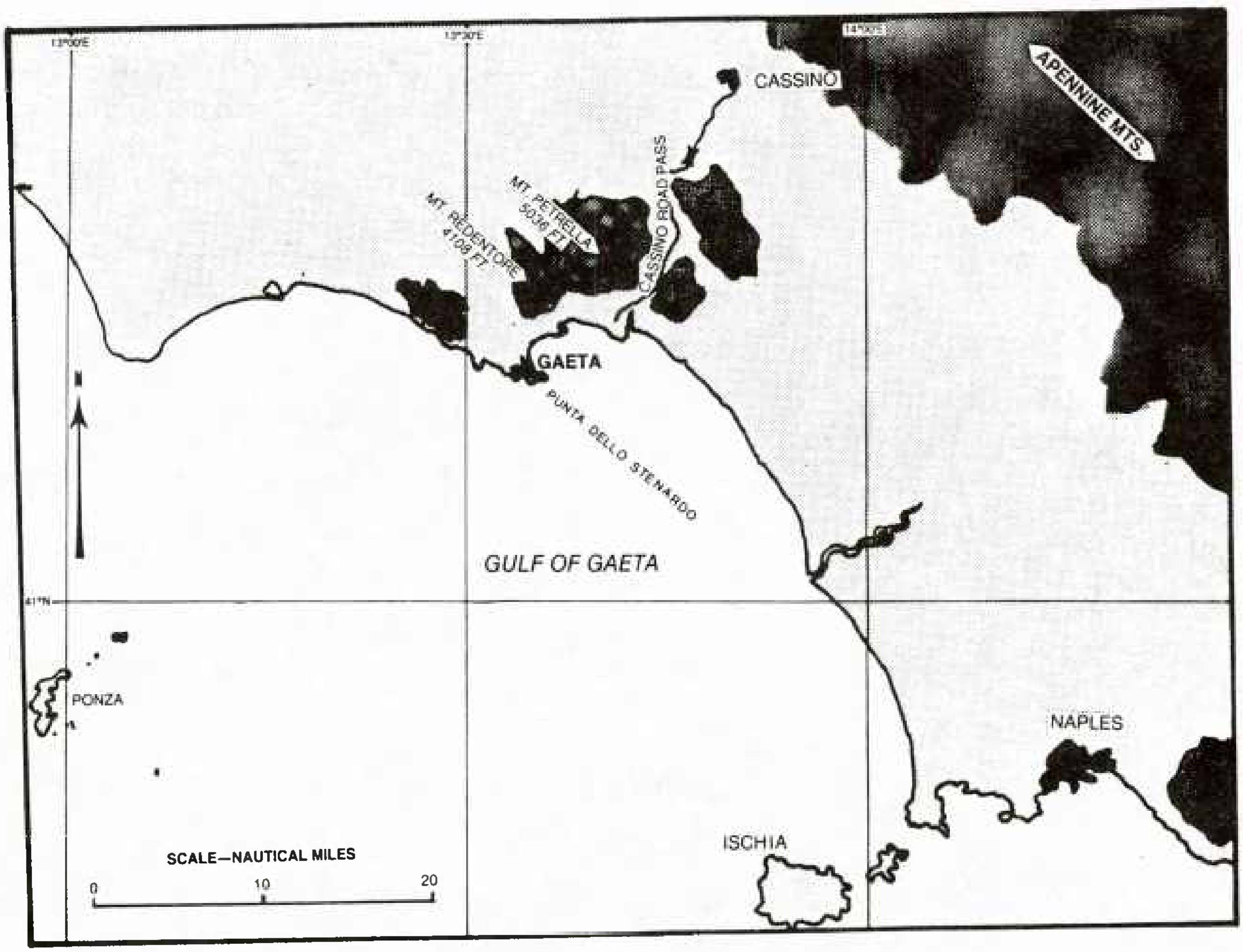


Figure 3-2. Gulf of Gaeta.

The Port of Gaeta is surrounded on three sides by terrain or man-made structures (Figure 3-3). There is a long breakwater on the east side of the harbor, the promontory of Punta dello Stenardo to the south, and the mainland of Italy to the west. At a farther distance, about 4 to 5 n mi, the mainland of Italy borders the north side of the harbor.

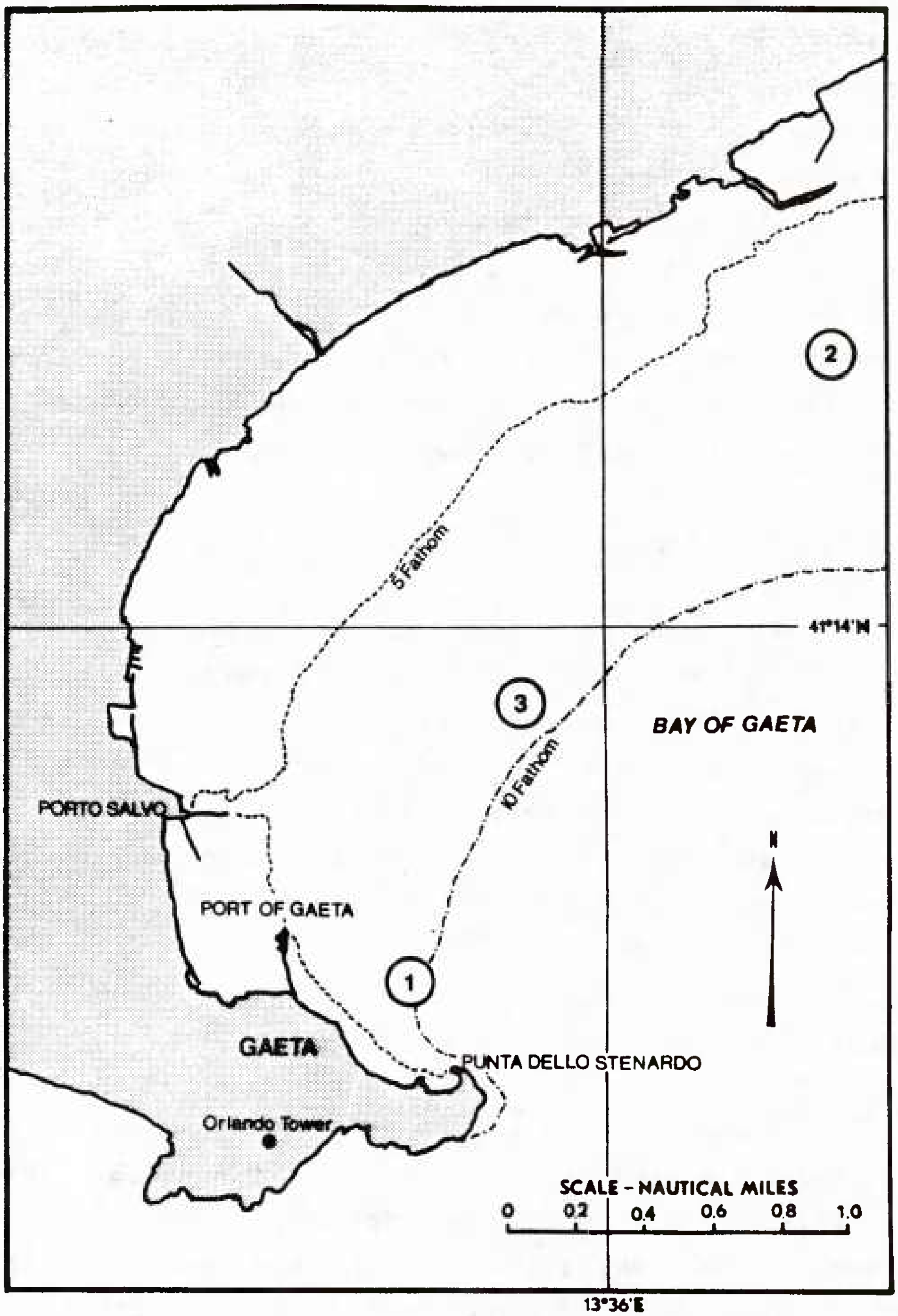


Figure 3-3. Port of Gaeta, Italy.

3.2 Qualitative Evaluation of Harbor as a Haven

The harbor at Gaeta is well protected and is used as a storm haven by vessels on the west coast of Italy with the knowledge that "if Gaeta is bad, no others are better". The Gulf of Gaeta south of Punta dello Stenardo is exposed to winds and waves from southeast clockwise through west. The portion of the Gulf north of Punta dello Stenardo is exposed to winds and waves from northeast through southeast. The inner harbor at Gaeta is protected on the east by a breakwater, thus limiting its exposure to wind waves generated in the limited fetch area north of the harbor entrance. The designated anchorage (Point 1 of Figure 3-3) is located east of the breakwater that protects the inner harbor, but the promontory of Punta dello Stenardo provides protection for anchored vessels from most swell generated in the open sea. The anchorage has a good mud bottom.

3.3 Currents and Tides

A south-moving ocean current, known locally as Corrente del Pontone, sets along the western shore of the Bay of Gaeta during southerly winds. When the wind veers northwesterly, the current changes to north-moving (Hydrographer of the Navy, 1965). In either case, the current is less than 1/2 knot. Tides at the Port of Gaeta are generally negligible with a tidal range of below 1 ft (0.3 m) (Lloyd's, 1983).

3.4 Visibility

Discussions with local harbor personnel reveal that haze (usually between 0600 and 0900 LST) reduces visibility to 3-4 n mi during spring, summer, and early autumn, often making the horizon and coastal features indistinguishable. Without mention of the actual minimum visibility, a local harbor pilot stated that visibilities less than 2 n mi have occurred only once in the 8 years he has been at the port.

3.5 Hazardous Conditions

The Port of Gaeta has limited exposure to large-scale hazardous wind and wave conditions. Several local wind (wave) conditions that are forced by the terrain (bathymetry) can result in hazardous conditions. A seasonal summary of the various known environmental hazards that may be encountered in the Port of Gaeta follows.

A. Winter (November through February)

The winter season is a time of cool temperatures, frequent precipitation, and relatively strong wind conditions at Gaeta. The proximity of Gaeta to one of the most active regions of cyclogenesis in the world -- the Gulf of Genoa -- dictates the unsettled winter weather conditions in the area.

The most significant weather problem during the winter season is the "Tramontana" wind, known locally as "Garigliano". This is a cold wind blowing down the Cassino Road Pass reaching Gaeta as an east-northeasterly (060°-075°) wind. The wind may reach force 8 (34-40 kt) or stronger during the night to mid-morning with the maximum speeds near sunrise. The wind usually decreases to force 5 (17-21 kt) during the afternoon. Moored vessels, nested vessels, vessel traffic in and out of the port, anchored vessels and small boat operations are all affected by the Tramontana wind. Port regulations state that vessels will not be moved in the inner harbor once winds exceed force 6 (22-27 kt). Vessels moored to piers may require tug assistance to remain secure to their berths since the east-northeasterly Tramontana wind will tend to force them off the piers. Moored ships should put on extra mooring lines during these extreme off-setting winds. To prevent potential groundings, anchored vessels will be notified by the Port Captain to move when winds reach force 6 (22-27 kt). Vessels can evade the worst effects of the wind by moving to the north-northwest section of the Bay of Gaeta which is in the lee of the Apennine Mountains.

Another potential winter hazard, although rare, is the Mistral wind. Originating as a gap wind blowing through the Rhone Valley south of Valence, France, it flows into the Gulf of Lion. A strong Mistral may extend through the Strait of Bonifacio (between Corsica and Sardinia) and affect Gaeta as a westerly wind of 30-35 kt lasting about 24 hours. Post-frontal winds also occur at Gaeta and are sometimes erroneously called the Mistral.

Open sea wind waves and swell are at their yearly high during the winter, but most of the wave energy tends to be refracted to the eastern part of the Bay of Gaeta and poses no significant problem to the inner harbor or designated anchorage (Point 1, Figure 3-3). Strong surf is raised along the shoreline between the Port of Gaeta and Porto Salvo (Figure 3-3). The Tramontana wind discussed earlier can raise 4-6 ft wind waves in the anchorage area (Point 1) and cause a disruption in boating operations throughout the harbor.

While the lowest recorded surface temperature at Gaeta is only 25°F (-4°C), wind chill (temperature combined with wind) can be very cold. For example, a temperature of 30°F (-1°C) and a wind velocity of 15 kt results in a wind chill of 10°F (-12°C). Table 3-1 can be used to determine wind chill for various temperature and wind combinations.

Table 3-1. Wind Chill. The cooling power of the wind expressed as "Equivalent Chill Temperature" (adapted from Kotsch, 1983).

Wind Speed		Cooling Power of Wind expressed as "Equivalent Chill Temperature"								
Knots	MPH	Temperature (°F)								
Calm	Calm	40	35	30	25	20	15	10	5	0
		Equivalent Chill Temperature								
3-6	5	35	30	25	20	15	10	5	0	-5
7-10	10	30	20	15	10	5	0	-10	-15	-20
11-15	15	25	15	10	0	-5	-10	-20	-25	-30
16-19	20	20	10	5	0	-10	-15	-25	-30	-35
20-23	25	15	10	0	-5	-15	-20	-30	-35	-45
24-28	30	10	5	0	-10	-20	-25	-30	-40	-50
29-32	35	10	5	-5	-10	-20	-30	-35	-40	-50
33-36	40	10	0	-5	-15	-20	-30	-35	-45	-55

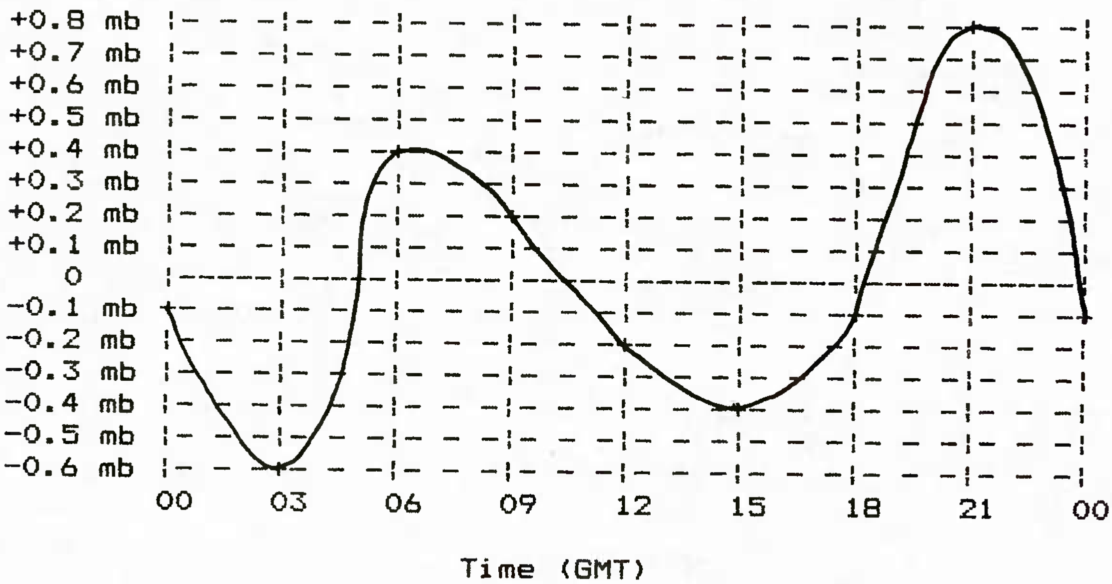
B. Spring (March through May)

Spring in Gaeta, through April, is characterized by periods of stormy winter-type weather which alternate with false starts of summer-type weather (Brody and Nestor, 1980). Wind chill remains a factor until May.

Prevailing winds are easterly during March becoming westerly in April and following months. Tramontana winds are a significant hazard through April after which they are infrequent until autumn. Mistral winds may occur during spring but frequency, extent, and severity become less pronounced as the season progresses.

As spring progresses, afternoon sea breezes become a more regular occurrence usually as a west-northwesterly wind of about force 3 (7-11 kt). Pressure rises west of Italy can cause an enhancement of the sea breeze, and increase its speed to force 5 (17-21 kt). The sea breeze can impact the moving of vessels in/out of a nest. It is recommended that all nesting maneuvers during late spring be conducted during morning hours. Figure 3-4 can be used to compare 3 or 6 hour pressure changes as a guide to determine if pressure rises are exceeding daily norms; an indicator that precedes enhanced sea breezes.

Figure 3-4. Average diurnal pressure changes at Gaeta during the annual period of sea breezes.



C. <u>Summer (June through September)</u>

Summer is a season of relatively settled, warm and dry weather in Gaeta, interrupted by an occasional Gulf of Genoa cyclone. Winds are generally light with a prevailing westerly direction June through August, and easterly during September.

Tramontana wind potential is reduced during summer months. However, the maximum winds for the months of June, August, and September are easterly -- reflecting the occurrence of local Tramontana events, land breezes, or highs over the Adriatic.

Mistral wind conditions in the Gulf of Lion may develop during any month, but the lowest frequencies of occurrence are observed during the August to November period. This is especially true for the relatively strong Mistrals (greater than force 6 (22-27 kt)). Since the stronger Mistrals of winter are the ones which are most likely to extend through the Strait of Bonifacio and affect Gaeta, Mistral conditions at Gaeta are at a minimum during the summer and autumn months.

Afternoon sea breezes are the rule, with west-northwesterly winds of force 3 (7-11 kt) usually observed. The sea breeze can cause problems when moving vessels in/out of a nest. Consequently, nesting maneuvers should be carried out during morning hours during the summer.

D. Autumn (October)

Autumn usually lasts only for the single month of October and is characterized by an abrupt change to winter-type weather at Gaeta and the adjacent Tyrrhenian Sea (Brody and Nestor, 1980).

The threat of local Tramontana winds increases as influxes of cold air begin to move across Europe in advance of the winter season. The threat of Mistral conditions remains low through November. Temperatures begin to decrease but the wind chill factor does not become significant until winter.

3.6 Harbor Protection

As detailed below, the Port of Gaeta is well protected from some wind directions, but is adversely affected by others. With respect to the effects of wave action, however, it is one of the best protected harbors on the Mediterranean Sea.

3.6.1 Wind and weather

Only the terrain north of the harbor affords any significant protection from wind. The Apennine Mountains, which dominate the countryside from west-northwest clockwise to northeast of the harbor, serve as an effective barrier to unrestricted northerly wind flow. The port is essentially vulnerable to winds from east-northeast clockwise to west-northwest. This results in exposure to the most common strong winds, the Tramontana, the Mistral, and the enhanced sea breezes of late spring and summer.

3.6.2 Waves

Harbor configuration provides almost total protection for the inner harbor and anchorage area 1 (Figure 3-3) from waves which have been generated in the open ocean. Some deep water swell will refract around Punta dello Stenardo and be felt in anchorage area 1. The longest unrestricted fetch area to which anchorage area 1 is exposed is about 30 n mi to the southeast. Waves generated as a result of southeasterly winds will be fetch limited. The outer parts of the harbor (anchorage area 3 on Figure 3-3) are exposed to deep water swell from the south and southwest. The northern part of the Bay (area 2 on Figure 3-3) provides protection from the Tramontana, but is unprotected for deep water swell from south clockwise through southwest.

Table 3-2 provides the shallow water wave conditions at the three designated points when deep water swell enters the harbor.

Example: Use of Table 3-2.

For a deep water wave condition of:
6 feet, 12 seconds, from 210°

The approximate shallow water wave conditions are:
Point 1: 2-3 feet, 12 seconds, from 110°
Point 2: 5-6 feet, 12 seconds, from 210°
Point 3: 2 feet, 12 seconds, from 170°

Table 3-2. Shallow water wave directions and relative height conditions versus deep water period and direction.

FORMAT: Shallow Water Direction
Height Ratio

GAETA POINT 1:

Deep Water Period (sec)	6	8	10	12	14
Direction					
180°	115° .5	110° .4	110° .4	110° .4	100° .6
210°	110° .3	120° .3	115° .3	110° .4	110° .6

GAETA POINT 2:

Deep Water Period (sec)	6	8	10	12	14
Direction					
180°	180° .8	180° .8	180° .9	180° .9	180° .9
210°	210° .8	210° .8	210° .9	210° .9	200° .9
240°	240° .8	240° .9	235° .9	235° .9	235° .9

GAETA POINT 3:

Deep Water Period (sec)	6	8	10	12	14
Direction					
180°	175° .5	165° .5	160° .7	165° .8	160° .7
210°	165° .3	160° .3	165° .3	170° .3	160° .3
240°	175° .2	180° .2	180° .2	180° .2	180° .2

Situation specific shallow water wave conditions resulting from deep water wave propagation are given in Table 3-2. The seasonal climatology of wave conditions in the harbor resulting from the propagation of deep water waves into the harbor are given in Table 3-3. If the actual or forecast deep water wave conditions are known, the expected conditions at the three specified harbor areas can be determined from Table 3-2. The mean duration of the condition, based on the shallow water wave heights, can be obtained from Table 3-3.

<u>Example: Use of Tables 3-2 and 3-3</u>.

The forecast for <u>wave conditions</u> tomorrow (winter case) <u>outside the harbor are</u>:

9 feet, 8 seconds, from 240°

Expected <u>shallow water conditions</u> and <u>duration</u>:

	Point 1	2	3
height	Protected	8 feet	2 feet
period	from	8 seconds	8 seconds
direction	240°	from 240°	from 180°
duration	swell	8 hours	NA

<u>NOTE</u>: Durations were not computed for heights less than 3.3 feet.

Interpretation of the information from Tables 3-2 and 3-3 provide guidance on the local wave conditions expected tomorrow at the various harbor points. The duration values are mean values for the specified height range and season. Knowledge of the <u>current synoptic pattern and forecast/expected duration should be used when available</u>.

Possible applications to small boat operations are selection of the mother ship's anchorage point and/or areas of small boat work. The condition duration information provides insight as to how long before a change can be expected. The local wave direction information could be of use in selecting anchorage configuration and related small boat operations.

Table 3-3. Shallow water climatology as determined from deep water wave propagation. Percent occurrence, average duration or persistence, and wave period of maximum energy for wave height ranges of greater than 3.3 feet and greater than 6.6 feet by climatological season.

GAETA POINT 1:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	11	6	2	10
Average Duration (hrs)	12	11	21	11
Period Max Energy (sec)	6	6	6	6
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	2	0	0	2
Average Duration (hrs)	8	NA	NA	9
Period Max Energy (sec)	9	NA	NA	9
GAETA POINT 2:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	15	9	4	13
Average Duration (hrs)	12	13	9	11
Period Max Energy (sec)	10	8	8	10
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	4	1	1	4
Average Duration (hrs)	8	9	8	9
Period Max Energy (sec)	14	12	12	12
GAETA POINT 3:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	13	8	4	14
Average Duration (hrs)	12	15	31	13
Period Max Energy (sec)	6	6	6	6
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	3	0	<<1	2
Average Duration (hrs)	8	NA	6	9
Period Max Energy (sec)	11	NA	11	11

Local wind wave conditions are provided in Table 3-4 for Gaeta point 3. The specified fetch lengths are specifically for point 3. The time to reach the fetch limited height assumes an initial flat ocean. With a pre-existing lower wave height, the times are shorter.

Example: Small boat wave forecasts (based on the assumption that swell is not a limiting factor).

Forecast for Tomorrow:

Time	Wind	Waves
prior to 0700 LST	light and variable	< 1 ft
0700 to 1200	ENE 8-10 kt	< 2 ft
1200 to 1500	ESE 22-26 kt	3-4 ft at 4 sec by 1400-1500
1500 to 2000	ESE 28-32 kt	4 ft at 4-5 sec by 1700
2000 to 2200	ESE 14-18 kt	3 ft or less at 4 sec by 2100

Interpretation: Assuming that the limiting factor is waves greater than 3 feet, small boat operations would be marginal by 1300 and restricted from about 1400 to 2100. Night operations could commence after 2100.

Table 3-4. Gaeta Bay near point 3. Local wind waves for fetch limited conditions related to point 3 (based on JONSWAP model).

Format: height (feet)/period (seconds)
time (hours) to reach fetch limited height

Direction and Fetch Length (n mi) \ Local Wind Speed (kt)	18	24	30	36	42
ENE 8 n mi	2/3 1-2	2-3/3-4 1-2	3/4 1-2	4/4 1-2	4-5/4-5 1-2
ESE 13 n mi	2-3/4 2	3-4/4 2-3	4/4-5 2	5/5 2	6/5 2
SSE 30 n mi	3-4/5 3	5/5-6 4	6/6 3-4	7/6 3-4	8/6-7 3

Combined wave heights are computed by finding the square root of the sum of the squares of the wind wave and swell heights. For example, if the wind waves were 3 ft and the swell 8 ft the combined height would be about 8.5 ft.

$$\sqrt{3^2 + 8^2} = \sqrt{9 + 64} = \sqrt{73} \approx 8.5$$

Note that the increased height is relatively small. Even if the two wave types were of equal height the combined height is only 1.4 times the common height. In cases where one of the heights is twice that of the other, the combined height will only increase over the larger of the two by 1.12 times (10 ft swell and 5 ft wind wave combined results in 11.2 ft height).

3.6.3 Wave data uses and considerations

Local wind waves build up quite rapidly and also decrease rapidly when winds subside. The period, and therefore length of wind waves, is generally short relative to the period and length of waves propagated into the harbor (see Appendix A). The shorter period and length result in wind waves being characterized by choppy conditions. When wind waves are superimposed on deep water waves propagated into shallow water, the waves can become quite complex and confused. Under such conditions, when more than one source of waves is influencing a location, tending or joint operations can be hazardous even if the individual wave train heights are not significantly high. Vessels of various lengths may respond in different motions to the different wave lengths present. The information on wave periods, provided in various tables, should be considered when forecasts are made for joint operations of various length vessels.

Wind waves can be a problem in the harbor area when a local Tramontana is occurring. A strong event can raise 4-6 ft seas in the harbor making small boat operations difficult. Most of the bothersome wind waves will occur in the anchorage areas and are greatly modified in the inner harbor. Other than operations involving small boats, the strong winds of the Tramontana present the greater hazard.

3.7 Protective/Mitigating Measures

3.7.1 Moving to new anchorage

When a local Tramontana (see section 3.5 A above) occurs, and upon the winds reaching force 6 (22-27 kt), the Port Captain will notify vessels to move from the designated anchorage to avoid dragging anchor and going aground on the Punta dello Stenardo promontory. Vessels desiring to avoid the highest winds and still remain at Gaeta can move to the north-northwest section of Gaeta Bay in the lee of the Apennine Mountains.

3.7.2 Sortie/remain in port

As stated in section 3.2 above, the Port of Gaeta is as protected as any port on the west coast of Italy so a sortie is usually not required. If it is determined to sortie, it should be commenced early enough to allow completion of inner harbor departure prior to the onset of force 6 (22-27 kt) winds. Due to the limited maneuvering room within the inner harbor and the limited tug assistance, vessels will not be moved once force 6 winds are occurring.

If a decision is made to remain in port, and high winds of Tramontana origin are expected, precautions must be taken. Moored vessels and nested vessels may need tug assistance and/or doubling of lines to remain at their moorings since the east-northeasterly winds will tend to force the vessels away from their moorings. Small boats should be firmly secured. Routine operations may be curtailed.

Since the harbor pilots will not move vessels in/out of a nest in winds of force 5 (17-21 kt) or greater, an enhanced sea breeze may affect nesting operations during summer and late spring. See Scheduling.

3.7.3 Scheduling

Harbor pilots will not move vessels in the inner harbor once winds reach force 6 (22-27 kt) and will not move vessels in or out of a nest after force 5 (17-21 kt) is reached. To avoid problems with wind, it is recommended that all arrivals, departures, or nesting operations be scheduled in early morning hours during summer and other seasons when the Tramontana is not occurring and when wind velocities are at their daily minimum. During Tramontana conditions wind velocities are at a minimum during the afternoon, however, they may still restrict ship movements.

3.8 Local Indicators of Hazardous Weather Conditions

The three conditions that pose the greatest problems for harbor operations at Gaeta are the winds of: (1) local Tramontana (east-northeast), (2) Mistral (west), and (3) enhanced sea breeze (west). The following guidelines may provide some forewarning of forthcoming high winds:

Tramontana - Winds are a result of a building high pressure center over northern Italy and a southeasterly moving low pressure center that is generated in the Gulf of Genoa and moves south of Gaeta. Fresh northerly flow funnels through the Cassino Road Pass in the Apennine Mountains east-northeast of Gaeta. Winds can be anticipated (12-24 hours advance warning) when fresh snow and/or small clouds are first visible on the summit of mountains to the north of Gaeta, including Mt. Redentore, a 4,108 ft (1,252 m) peak located about 6 n mi north of Gaeta. Persistent snow on these mountain tops is an indicator of continued cold northerly flow and locally strong northeast winds. The onset of strong winds may occur before snow is visible. The winter snows and the wind condition occur just after frontal passages. The building of a cold continental high north of the Alps is the prime indicator of potential Tramontana development.

If the pressure gradient along the east coast of Italy is measured between Trieste and Brindisi (with Trieste higher), the following winds can be expected at Gaeta: 8 mb difference = 20-30 kt; 12 mb difference = 30-40 kt; and 16 mb difference = 40-50 kt. The wind velocities will start to decrease when the high pressure center moves east of 15°E.

Mistral - Watch for wind warnings for the Gulf of Lion and Strait of Bonifacio (between Corsica and Sardinia). Mistral winds will occur first in the Gulf of Lion, and then in the Strait of Bonifacio. A true Mistral will be experienced at Gaeta only after it first occurs in the Strait of Bonifacio.

High winds following the passage of a strong low pressure system or frontal system are frequently erroneously referred to as Mistral. It is only a technical difference, however, as the effects are generally the same.

Enhanced sea breeze - Afternoon sea breezes should be expected daily in late spring. Enhanced sea breezes (winds stronger than force 3 (7-10 kt)) are usually a result of increasing atmospheric pressures to the west, resulting in a strengthened pressure gradient over Gaeta. Section 3.5 B contains a guide for use in determining if pressure rises exceed the daily norm.

3.9 Summary of Problems, Actions, and Indicators

Table 3-5 is intended to provide easy to use seasonal references for meteorologists on ships using the Port of Gaeta. Table 2-1 of the summary section summarizes Table 3-5 and is intended primarily for use by ship's personnel where no meteorologist is available. Tables 3-2 through 3-4 provide additional information on swell propagation into the harbor, local wind waves, and shallow water climatology. The hazardous conditions are addressed in paragraph 3.5 by season.

Table 3-5. Potential problem situations at Port of Gaeta - ALL SEASONS.

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
1. Moored - no nested vessels. Winter Spring Rare in Summer Autumn	a. Tramontana wind - Strong ENE'ly winds known locally as a Garigliano. Strongest during late evening to mid-morning, weakest early afternoon. May reach force 8 (34-40 kts) or stronger, decreasing to force 5 (17-22 kts) during early afternoon. Probability of such winds is greatly reduced in summer.	a. Port of Gaeta is considered safe during high winds but tug assistance may be required to remain at pier; wind will tend to force moored vessels off their mooring. Due to restricted maneuvering room and low powered tugs, vessels scheduled to moor or get underway should do so prior to onset of force 5 (17-21 kts) winds. Once winds reach force 6 (22-27 kts), vessels will not be moved in the port. Small craft should be well secured.	a. Winds are a result of a building high pressure center over northern Italy and a SE'ly moving low pressure center that is normally generated in the Gulf of Genoa. Fresh northerly flow funnels through the Cassino Road Pass and the Garigliano River Valley in the Appenine Mountains ENE of Gaeta. Winds can be anticipated (12-24 hours advance warning) when small clouds are first visible on the summit of mountains to the north of Gaeta, including Mt. Redentore, a 4,108 ft peak located about 6 n mi NE of Gaeta. If the pressure gradient is measured between Trieste and Brindisi (on Italy's east coast), the following winds can be expected at Gaeta: 8 mb (with Trieste higher) = 20-30 kts; 12 mb = 30-40 kts; and 16 mb = 40-50 kts. The wind velocities will start to decrease when the low pressure center moves east of 15°E.
Winter Spring Minimum Late Summer Autumn	b. Mistral wind - Occurs at Gaeta as westerly 30-35 kts. Usually lasts for about 24 hrs. The frequency of occurrence is at a minimum in late summer. Post-frontal winds are sometimes erroneously called Mistral, effects are similar.	b. Remain at berth. Westerly wind will tend to keep vessel against pier(s).	b. Watch for wind warnings for Gulf of Lion, Strait of Bonifacio and Tyrrhenian Sea. True Mistral winds will occur first in the Gulf of Lion, and then in the Strait of Bonifacio. If winds are actually post-frontal type rather than Mistral, they will follow a strong cold or occluded frontal passage.
Winter Spring Summer Autumn	c. SE to SW swell.	c. Remain at berth. Swell energy tends to be refracted to the eastern part of Gaeta Bay and should pose no problem in the harbor. Waves may cause strong surf conditions along the coast between Gaeta and Porto Salvo.	c. If low pressure center and/or frontal system are forecast to move through the area, S'ly winds ahead of the disturbance may produce SE to SW swell in Gulf of Gaeta. Wind and swell directions will tend to remain from the same direction except for a short period following a major wind shift such as a frontal passage.
2. Moored with tended vessels nested. Winter Spring Uncommon in Summer Autumn	a. Tramontana wind - Strong ENE'ly winds known locally as a Garigliano. Strongest during late evening to mid-morning, weakest early afternoon. May reach force 8 (34-40 kts) or stronger, decreasing to force 5 (17-22 kts) during early afternoon. Probability of such winds is greatly reduced after April and throughout summer.	a. Port of Gaeta is considered safe during high winds but tug assistance may be required to remain at pier; wind will tend to force moored vessels off their mooring. Due to restricted maneuvering room and low powered tugs, vessels scheduled to moor or get underway should do so prior to onset of force 5 (17-21 kts) winds. Once winds reach force 6 (22-27 kts), vessels will not be moved in the port. Small craft should be well secured. Nested vessels experience no major problems as long as wind remains E'ly. If wind should back to N'ly, nested vessels will be out of tender's lee and may shift.	a. Winds are a result of a building high pressure center over northern Italy and a SE'ly moving low pressure center that is normally generated in the Gulf of Genoa. Fresh northerly flow funnels through the Cassino Road Pass and the Garigliano River Valley in the Appenine Mountains ENE of Gaeta. Winds can be anticipated (12-24 hours advance warning) when small clouds are first visible on the summit of mountains to the north of Gaeta, including Mt. Redentore, a 4,108 ft peak located about 6 n mi NE of Gaeta. If the pressure gradient is measured between Trieste and Brindisi (on Italy's east coast), the following winds can be expected at Gaeta: 8 mb (with Trieste higher) = 20-30 kts; 12 mb = 30-40 kts; and 16 mb = 40-50 kts. The wind velocities will start to decrease when the low pressure center moves east of 15°E.
Winter Spring Minimum Late Summer Autumn	b. Mistral wind - Occurs at Gaeta as westerly 30-35 kts. Usually lasts for about 24 hrs. The frequency of occurrence is at a minimum in late summer. Post-frontal winds are sometimes erroneously called Mistral, effects are similar.	b. Nested vessels should experience no major problems. Moving vessels in/out of nest during Mistral conditions should be avoided due to limited maneuvering room, limitations of tug assistance, and exposure of nest to W'ly wind.	b. Watch for wind warnings for Gulf of Lion, Strait of Bonifacio and Tyrrhenian Sea. True Mistral winds will occur first in the Gulf of Lion, and then in the Strait of Bonifacio. If winds are actually post-frontal type rather than Mistral, they will follow a strong cold or occluded frontal passage.
Spring Summer Autumn	c. Sea breeze. WNW'ly force 3 (7-11 kts) sea breeze routinely occurs during afternoons in summer. An enhanced sea breeze (see section 1.2.2) can exceed force 5 (17-21 kts).	c. Nested vessels should experience no problems. However, moving vessels in/out of nest should be avoided during afternoon hours due to limited maneuvering room, limitations of tug assistance, and exposure of nest to W'ly winds. Local pilots will not bring a vessel alongside in a nest in winds of force 5 (17-21 kts) or greater.	c. Afternoon sea breezes should be expected daily in summer. Enhanced sea breezes (winds stronger than force 3 (7-11 kts) are usually a result of increasing atmospheric pressures to the west, resulting in a strengthened pressure gradient over Gaeta. See section 3.5 B for a guide to assist in determining if pressure rises exceed the daily norm.

Table 3-5. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
3. Anchored in designated anchorage. Winter Spring Rare in Summer Autumn	a. Tramontana wind - Strong ENE'ly winds known locally as a Garigliano. Strongest during late evening to mid-morning, weakest early afternoon. May reach force 8 (34-40 kts) or stronger, decreasing to force 5 (17-22 kts) during early afternoon. Probability of such winds is greatly reduced after April and throughout summer.	a. Anchored vessels will be notified to move by Port Captain when winds reach force 6 (22-27 kts). Highest winds can be evaded by moving to the NNW section of Gaeta Bay in the lee of the Apennine Mountains. High winds will cause cancellation of boating to/from anchorages when wind reaches 40 kts or 4-6 ft seas occur.	a. Winds are a result of a building high pressure center over northern Italy and a SE'ly moving low pressure center that is normally generated in the Gulf of Genoa. Fresh northerly flow funnels through the Cassino Road Pass and the Garigliano River Valley in the Appenine Mountains ENE of Gaeta. Winds can be anticipated (12-24 hours advance warning) when small clouds are first visible on the summit of mountains to the north of Gaeta, including Mt. Redentore, a 4,108 ft peak located about 6 n mi NE of Gaeta. If the pressure gradient is measured between Trieste and Brindisi (on Italy's east coast), the following winds can be expected at Gaeta: 8 mb (with Trieste higher) = 20-30 kts; 12 mb = 30-40 kts; and 16 mb = 40-50 kts. The wind velocities will start to decrease when the low pressure center moves east of 15°E.
Winter Spring Minimum Late Summer Autumn	b. Mistral wind - Occurs at Gaeta as westerly 30-35 kts. Usually lasts for about 24 hrs. The frequency of occurrence is at a minimum in late summer. Post-frontal winds are sometimes erroneously called Mistral, effects are similar.	b. Anchor may drag but drift should be toward deeper water east of anchorage. Small boating may be restricted. High winds will cause cancellation of boating to/from anchorages when wind reaches 40 kts or 4-6 ft seas occur.	b. Watch for wind warnings for Gulf of Lion, Strait of Bonifacio and Tyrrhenian Sea. True Mistral winds will occur first in the Gulf of Lion, and then in the Strait of Bonifacio. If winds are actually post-frontal type rather than Mistral, they will follow a strong cold or occluded frontal passage.
Winter Spring Summer Autumn	c. SE to SW swell.	c. Small boating may be restricted. High winds will cause cancellation of boating to/from anchorages when wind reaches 40 kts or 4-6 ft seas occur.	c. If low pressure center and/or frontal system are forecast to move through the area, S'ly winds ahead of the disturbance may produce SE to SW swell in Gulf of Gaeta. Wind and swell directions will tend to remain from the same direction except for a short period following a major wind shift such as a frontal passage.
4. Arriving/departing harbor. Winter Spring Rare in Summer Autumn	a. Tramontana wind - Strong ENE'ly winds known locally as a Garigliano. Strongest during late evening to mid-morning, weakest early afternoon. May reach force 8 (34-40 kts) or stronger, decreasing to force 5 (17-22 kts) during early afternoon. Probability of such winds is greatly reduced after April and throughout summer.	a. Schedule for completion prior to onset of forecast force 5 (17-21 kts) winds. Vessels will not be moved in the port once winds reach force 6 (22-27 kts). Anchored vessels will be notified to move by Port Captain when winds reach force 6 (22-27 kts). Highest winds can be evaded by moving to the NNW section of Gaeta Bay. High winds will cause cancellation of boating to/from anchorages when wind reaches 40 kts or 4-6 ft seas occur. If vessels are being moved in or out of a nest, movement must be completed prior to onset of force 5 (17-21 kts) winds.	a. Winds are a result of a building high pressure center over northern Italy and a SE'ly moving low pressure center that is normally generated in the Gulf of Genoa. Fresh northerly flow funnels through the Cassino Road Pass and the Garigliano River Valley in the Appenine Mountains ENE of Gaeta. Winds can be anticipated (12-24 hours advance warning) when small clouds are first visible on the summit of mountains to the north of Gaeta, including Mt. Redentore, a 4,108 ft peak located about 6 n mi NE of Gaeta. If the pressure gradient is measured between Trieste and Brindisi (on Italy's east coast), the following winds can be expected at Gaeta: 8 mb (with Trieste higher) = 20-30 kts; 12 mb = 30-40 kts; and 16 mb = 40-50 kts. The wind velocities will start to decrease when the low pressure center moves east of 15°E.
Winter Spring Minimum Late Summer Autumn	b. Mistral wind - Occurs at Gaeta as westerly 30-35 kts. Usually lasts for about 24 hrs. The frequency of occurrence is at a minimum in late summer. Post-frontal winds are sometimes erroneously called Mistral, effects are similar.	b. Schedule for completion prior to onset of forecast force 5 (17-21 kts) winds. Vessels will not be moved in the port once winds reach force 6 (22-27 kts). Anchored vessels will be notified to move by Port Captain when winds reach force 6 (22-27 kts). Highest winds can be evaded by moving to the NNW section of Gaeta Bay. High winds will cause cancellation of boating to/from anchorages when wind reaches 40 kts or 4-6 ft seas occur. If vessels are being moved in or out of a nest, movement must be completed prior to onset of force 5 (17-21 kts) winds.	b. Watch for wind warnings for Gulf of Lion, Strait of Bonifacio and Tyrrhenian Sea. True Mistral winds will occur first in the Gulf of Lion, and then in the Strait of Bonifacio. If winds are actually post-frontal type rather than Mistral, they will follow a strong cold or occluded frontal passage.
5. Small boat operations. Winter Spring Rare in Summer Autumn	a. Tramontana wind - Strong ENE'ly winds known locally as a Garigliano. Strongest during late evening to mid-morning, weakest early afternoon. May reach force 8 (34-40 kts) or stronger, decreasing to force 5 (17-22 kts) during early afternoon. Probability of such winds is greatly reduced after April and throughout summer.	a. High winds will cause cancellation of boating to/from anchorages when wind reaches 40 kts or 4-6 ft seas occur.	a. Winds are a result of a building high pressure center over northern Italy and a SE'ly moving low pressure center that is normally generated in the Gulf of Genoa. Fresh northerly flow funnels through the Cassino Road Pass and the Garigliano River Valley in the Appenine Mountains ENE of Gaeta. Winds can be anticipated (12-24 hours advance warning) when small clouds are first visible on the summit of mountains to the north of Gaeta, including Mt. Redentore, a 4,108 ft peak located about 6 n mi NE of Gaeta. If the pressure gradient is measured between Trieste and Brindisi (on Italy's east coast), the following winds can be expected at Gaeta: 8 mb (with Trieste higher) = 20-30 kts; 12 mb = 30-40 kts; and 16 mb = 40-50 kts. The wind velocities will start to decrease when the low pressure center moves east of 15°E.
Winter	b. Mistral wind - Occurs at Gaeta as westerly 30-35 kts. Usually lasts for about 24 hrs. Post-frontal winds are sometimes erroneously called Mistral, effects are similar.	b. Anchor may drag but drift should be toward deeper water east of anchorage. Small boating may be restricted. High winds will cause cancellation of boating to/from anchorages when wind reaches 40 kts or 4-6 ft seas occur.	b. Watch for wind warnings for Gulf of Lion, Strait of Bonifacio and Tyrrhenian Sea. True Mistral winds will occur first in the Gulf of Lion, and then in the Strait of Bonifacio. If winds are actually post-frontal type rather than Mistral, they will follow a strong cold or occluded frontal passage.

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PORT VISIT INFORMATION

JUNE 1985. NEPRF meteorologists R. Fett and R. Picard met with Sixth Fleet meteorologists CDR Williams and AGCS Elmers, the Port Captain and the Senior Pilot to obtain much of the information included in this port evaluation.

APPENDIX A

General Purpose Oceanographic Information

This section provides general information on wave forecasting and wave climatology as used in this study. The forecasting material is not harbor specific. The material in paragraphs A.1 and A.2 was extracted from H.O. Pub. No. 603, Practical Methods for Observing and Forecasting Ocean Waves (Pierson, Neumann, and James, 1955). The information on fully arisen wave conditions (A.3) and wave conditions within the fetch region (A.4) is based on the JONSWAP model. This model was developed from measurements of wind wave growth over the North Sea in 1973. The JONSWAP model is considered more appropriate for an enclosed sea where residual wave activity is minimal and the onset and end of locally forced wind events occur rapidly (Thornton, 1986), and where waves are fetch limited and growing (Hasselmann, et al., 1976). Enclosed sea, rapid onset/subsiding local winds, and fetch limited waves are more representative of the Mediterranean waves and winds than the conditions of the North Atlantic from which data was used for the Pierson and Moskowitz (P-M) Spectra (Neumann and Pierson 1966). The P-M model refined the original spectra of H.O. 603, which over developed wave heights.

The primary difference in the results of the JONSWAP and P-M models is that it takes the JONSWAP model longer to reach a given height or fully developed seas. In part this reflects the different starting wave conditions. Because the propagation of waves from surrounding areas into semi-enclosed seas, bays, harbors, etc. is limited, there is little residual wave action following periods of locally light/calm winds and the sea surface is nearly flat. A local wind developed wave growth is therefore slower than wave growth in the open ocean where some residual wave action is generally always present. This slower wave development is a built in bias in the formulation of the JONSWAP model which is based on data collected in an enclosed sea.

A.1 Definitions

Waves that are being generated by local winds are called "SEA". Waves that have traveled out of the generating area are known as "SWELL". Seas are chaotic in period, height and direction while swell approaches a simple sine wave pattern as its distance from the generating area increases. An in-between state exists for a few hundred miles outside the generating area and is a condition that reflects parts of both of the above definitions. In the Mediterranean area, because its fetches and open sea expanses are limited, SEA or IN- BETWEEN conditions will prevail. The "SIGNIFICANT WAVE HEIGHT" is defined as the average value of the heights of the one-third highest waves. PERIOD and WAVE LENGTH refer to the time between passage of, and distances between, two successive crests on the sea surface. The FREQUENCY is the reciprocal of the period (f = 1/T) therefore as the period increases the frequency decreases. Waves result from the transfer of energy from the wind to the sea surface. The area over which the wind blows is known as the FETCH, and the length of time that the wind has blown is the DURATION. The characteristics of waves (height, length, and period) depend on the duration, fetch, and velocity of the wind. There is a continuous generation of small short waves from the time the wind starts until it stops. With continual transfer of energy from the wind to the sea surface the waves grow with the older waves leading the growth and spreading the energy over a greater range of frequencies. Throughout the growth cycle a SPECTRUM of ocean waves is being developed.

A.2 Wave Spectrum

Wave characteristics are best described by means of their range of frequencies and directions or their spectrum and the shape of the spectrum. If the spectrum of the waves covers a wide range of frequencies and directions (known as short-crested conditions), SEA conditions prevail. If the spectrum covers a narrow range of frequencies and directions (long crested conditions), SWELL conditions prevail. The wave spectrum depends on the duration of the wind, length of the fetch, and on the wind velocity. At a given wind speed and a given state of wave development, each spectrum has a band of frequencies where most of the total energy is concentrated. As the wind speed increases the range of significant frequencies extends more and more toward lower frequencies (longer periods). The frequency of maximum energy is given in equation 1.1 where v is the wind speed in knots.

$$f_{max} = \frac{2.476}{v} \qquad (1.1)$$

The wave energy, being a function of height squared, increases rapidly as the wind speed increases and the maximum energy band shifts to lower frequencies. This results in the new developing smaller waves (higher frequencies) becoming less significant in the energy spectrum as well as to the observer. As larger waves develop an observer will pay less and less attention to the small waves. At the low frequency (high period) end the energy drops off rapidly, the longest waves are relatively low and extremely flat, and therefore also masked by the high energy frequencies. The result is that 5% of the upper frequencies and 3% of the lower frequencies can be cut-off and only the remaining frequencies are considered as the "significant part of the wave spectrum". The resulting range of significant frequencies or periods are used in defining a fully arisen sea. For a fully arisen sea the approximate average period for a given wind speed can be determined from equation (1.2).

$$\bar{T} = 0.285v \qquad (1.2)$$

Where v is wind speed in knots and T is period in seconds. The approximate average wave length in a fully arisen sea is given by equation (1.3).

$$\bar{L} = 3.41\ \bar{T}^2 \qquad (1.3)$$

Where $\bar{L}$ is average wave length in feet and $\bar{T}$ is average period in seconds.

The approximate average wave length of a fully arisen sea can also be expressed as:

$$\bar{L} = .67\text{"L"} \qquad (1.4)$$

where "L" = $5.12T^2$, the wave length for the classic sine wave.

A.3 Fully Arisen Sea Conditions

For each wind speed there are minimum fetch (n mi) and duration (hr) values required for a fully arisen sea to exist. Table A-1 lists minimum fetch and duration values for selected wind speeds, values of significant wave (average of the highest 1/3 waves) period and height, and wave length of the average wave during developing and fully arisen seas. The minimum duration time assumes a start from a flat sea. When pre-existing lower waves exist the time to fetch limited height will be shorter. Therefore the table duration time represents the maximum duration required.

Table A-1. Fully Arisen Deep Water Sea Conditions Based on the JONSWAP Model.

Wind Speed (kt)	Minimum Fetch/Duration (n mi) (hrs)	Sig Wave (H1/3) Period/Height (sec) (ft)	Wave Length (ft)[1,2] Developing/Fully /Arisen L X (.5) /L X (.67)
10	28 / 4	4 / 2	41 / 55
15	55 / 6	6 / 4	92 / 123
20	110 / 8	8 / 8	164 / 220
25	160 / 11	9 / 12	208 / 278
30	210 / 13	11 / 16	310 / 415
35	310 / 15	13 / 22	433 / 580
40	410 / 17	15 / 30	576 / 772

NOTES:

[1] Depths throughout fetch and travel zone must be greater than 1/2 the wave length, otherwise shoaling and refraction take place and the deep water characteristics of waves are modified.

[2] For the classic sine wave the wave length (L) equals 5.12 times the period (T) squared ($L = 5.12T^2$). As waves develop and mature to fully developed waves and then propagate out of the fetch area as swell their wave lengths approach the classic sine wave length. Therefore the wave lengths of developing waves are less than those of fully developed waves which in turn are less than the length of the resulting swell. The factor of .5 (developing) and .67 (fully developed) reflect this relationship.

A.4 <u>Wave Conditions Within The Fetch Region</u>

Waves produced by local winds are referred to as SEA. In harbors the local sea or wind waves may create hazardous conditions for certain operations. Generally within harbors the fetch lengths will be short and therefore the growth of local wind waves will be fetch limited. This implies that there are locally determined upper limits of wave height and period for each wind velocity. Significant changes in speed or direction will result in generation of a new wave group with a new set of height and period limits. Once a fetch limited sea reaches its upper limits no further growth will occur unless the wind speed increases.

Table A-2 provides upper limits of period and height for given wind speeds over some selected fetch lengths. The duration in hours required to reach these upper limits (assuming a start from calm and flat sea conditions) is also provided for each combination of fetch length and wind speed. Some possible uses of Table A-2 information are:

1) If the only waves in the area are locally generated wind waves, the Table can be used to forecast the upper limit of sea conditions for combinations of given wind speeds and fetch length.

2) If deep water swell is influencing the local area in addition to locally generated wind waves, then the Table can be used to determine the wind waves that will combine with the swell. Shallow water swell conditions are influenced by local bathymetry (refraction and shoaling) and will be addressed in each specific harbor study.

3) Given a wind speed over a known fetch length the maximum significant wave conditions and time needed to reach this condition can be determined.

Table A-2. Fetch Limited Wind Wave Conditions and Time Required to Reach These Limits (Based on JONSWAP Model). Enter the table with wind speed and fetch length to determine the significant wave height and period, and time duration needed for wind waves to reach these limiting factors. All of the fetch/speed combinations are fetch limited except the 100 n mi fetch and 18 kt speed.

Format: height (feet)/period (seconds)
duration required (hours)

Fetch Length (n mi) \ Wind Speed (kt)	18	24	30	36	42
10	2/3-4 1-2	3/3-4 2	3-4/4 2	4/4-5 1-2	5/5 1-2
20	3/4-5 2-3	4/4-5 3	5/5 3	6/5-6 3-4	7/5-6 3
30	3-4/5 3	5/5-6 4	6/6 3-4	7/6 3-4	8/6-7 3
40	4-5/5-6 4-5	5/6 4	6-7/6-7 4	8/7 4	9-10/7-8 3-4
100	5/6-7[1] 5-6	9/8 8	11/9 7	13/9 7	15-16/9-10 7

[1] 18 kt winds are not fetch limited over a 100 n mi fetch.

An example of expected wave conditions based on Table A-2 follows:

WIND FORECAST OR CONDITION

An offshore wind of about 24 kt with a fetch limit of 20 n mi (ship is 20 n mi from the coast) is forecast or has been occurring.

SEA FORECAST OR CONDITION

From Table A-2: If the wind condition is forecast to last, or has been occurring, for at least 3 hours:

Expect sea conditions of 4 feet at 4-5 second period to develop or exist. If the condition lasts less than 3 hours the seas will be lower. If the condition lasts beyond 3 hours the sea will not grow beyond that developed at the end of about 3 hours unless there is an increase in wind speed or a change in the direction that results in a longer fetch.

A.5 Wave Climatology

The wave climatology used in these harbor studies is based on 11 years of Mediterranean SOWM output. The MED-SOWM is discussed in Volume II of the U.S. Naval Oceanography Command Numerical Environmental Products Manual (1986). A deep water MED-SOWM grid point was selected as representative of the deep water wave conditions outside each harbor. The deep water waves were then propagated into the shallow water areas. Using linear wave theory and wave refraction computations the shallow water climatology was derived from the modified deep water wave conditions. This climatology does not include the local wind generated seas. This omission, by design, is accounted for by removing all wave data for periods less than 6 seconds in the climatology. These shorter period waves are typically dominated by locally generated wind waves.

A.6 Propagation of Deep Water Swell Into Shallow Water Areas

When deep water swell moves into shallow water the wave patterns are modified, i.e., the wave heights and directions typically change, but the wave period remains constant. Several changes may take place including shoaling as the wave feels the ocean bottom, refraction as the wave crest adjusts to the bathymetry pattern, changing so that the crest becomes more parallel to the bathymetry contours, friction with the bottom sediments, interaction with currents, and adjustments caused by water temperature gradients. In this work, only shoaling and refraction effects are considered. Consideration of the other factors are beyond the resources available for this study and, furthermore, they are considered less significant in the harbors of this study than the refraction and shoaling factors.

To determine the conditions of the deep water waves in the shallow water areas the deep water conditions were first obtained from the Navy's operational MED-SOWM wave model. The bathymetry for the harbor/area of interest was extracted from available charts and digitized for computer use. Figure A-1 is a sample plot of bathymetry as used in this project. A ray path refraction/shoaling program was run for selected combinations of deep water wave direction and period. The selection was based on the near deep water wave climatology and harbor exposure. Each study area requires a number of ray path computations. Typically there are 3 or 4 directions (at 30° increments) and 5 or 6 periods (at 2 second intervals) of concern for each area of study. This results in 15 to 24 plots per area/harbor. To reduce this to a manageable format for quick reference, specific locations within each study area were selected and the information was summarized and is presented in the specific harbor studies in tabular form.

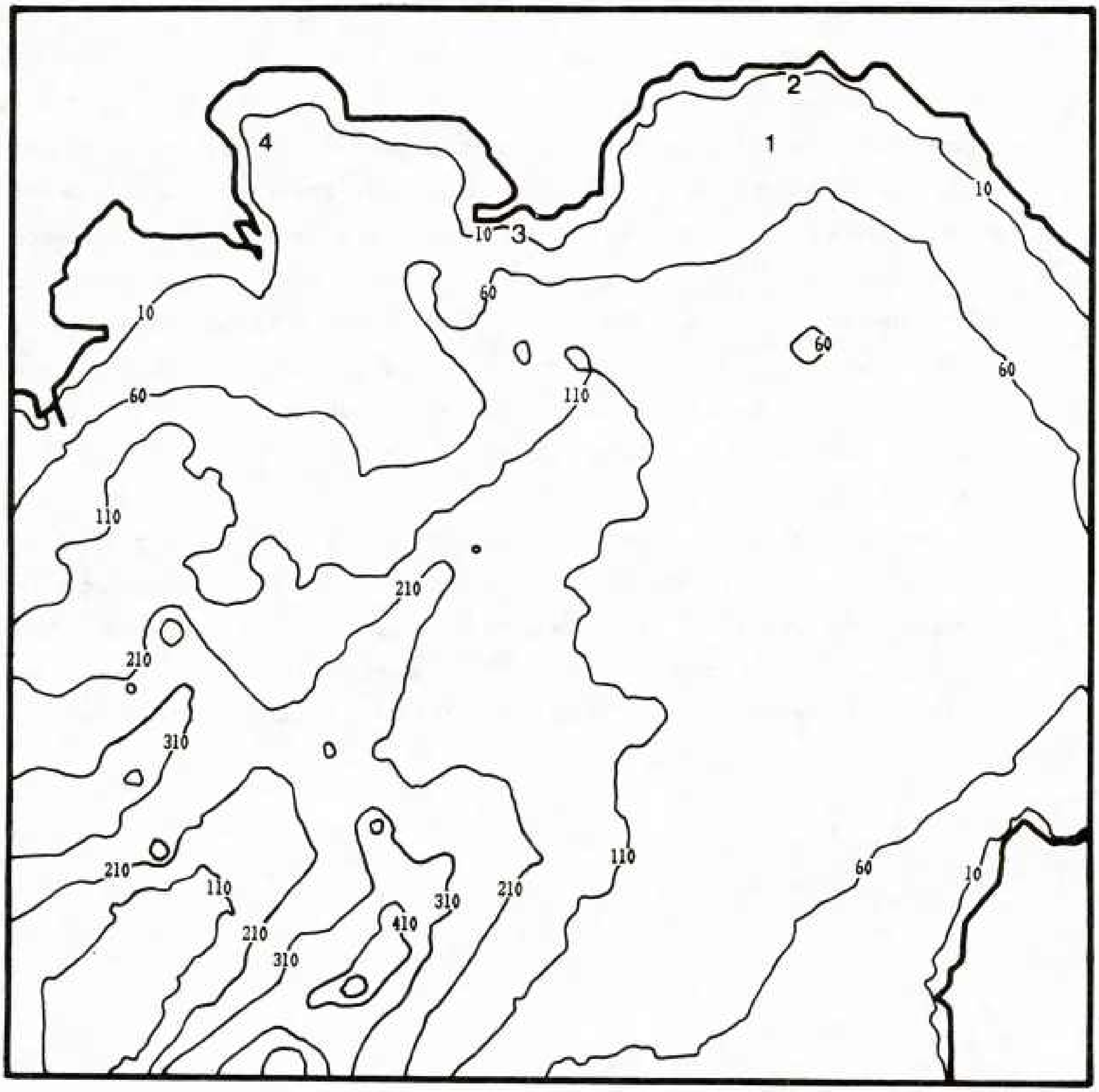

Figure A-1. Example plot of bathymetry (Naples harbor) as used in this project. For plotting purposes only, contours are at 50 fathom intervals from an initial 10 fathoms to 110 fathoms, and at 100 fathom intervals thereafter. The larger size numbers identify specific anchorage areas addressed in the harbor study.

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